Graphic Claymation – Visualization Through Sight And Touch

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Introduction:

“Introduction to Graphics and Solids Modeling” (METBD 110) is a first semester freshmen class for all students enrolled in the Plastics Engineering Technology (PLET) and Mechanical Engineering Technology (MET) programs in both the associate and bachelors programs offered at Penn State Erie, The Behrend College. This class is a three-credit course, which meets five hours per week for 14 weeks in a supervised lab setting. Since it is a first semester course, there are no prerequisites and there are no assumptions that the student has any sort of graphics or CAD background from high school. This course was taught using Pro/ENGINEER® (Pro/E), which is the main CAD program used at Penn State Erie. During the fall semesters of both 2001 and 2002, five sections of approximately 20 students each, were taught using the same three instructors in both semesters. All three instructors followed the same syllabus and taught the class in essentially the same manner.

The main goals of METBD 110 were as follows: First, to give the students a firm background in the basics of graphics - sketching 2-dimensional (2D) views, isometric (3D) views and dimensioning rules following ASME Y14.5M-1994 standards.[(1)] Second, the concepts of solid modeling using Pro/E, which included menus, constraints, dimensioning, orientation and the use of all “create/feature” options as well as creating drawings with dimensions from a solid model. Sectioning and auxiliary views were covered on a need to know basis.

The text used for the course was *Modern Graphics Communication*, Giesecke, Mitchell, Spencer, Hill, Dygdon, Novak, Lockhart, as this traditional text covers the basics of sketching and dimensioning.[(2)] The teaching of CAD at Penn State Erie has evolved over about a fifteen-year period. The graphics faculty have not found a textbook that covers material in a fashion that suits Penn State Erie’s course topics. Therefore students download material from the instructor’s website on each aspect that was covered in addition to the textbook. The class was structured with a lecture at the start of class followed by practice and homework.

During the American Society for Engineering Education 2002 National Conference, the paper titled “Process Education in Computer Graphics” (Session 1338) was presented to describe the changes in the Penn State Erie graphics courses.[(3)] As stated in the paper, changes in the student culture have dictated the need to change our approach to teaching, making it necessary for the instructors to reevaluate their teaching methods and how the material was presented to the students. The desire to improve our students’ performance and find a way to have the student be more prepared for class prompted the faculty to apply a process education approach to instruction in the fall of 2001. Process education is another name for active learning which is “an educational philosophy which focuses on building students’ learning skills (in all domains) and developing “self growers””.[(4)] The previous paper describes the trials and tribulations for three levels of graphics course during the fall of 2001. As a result from these changes, it was determined that the visualization skills of the students were the largest stumbling block. Without these skills, the students had difficulty in proceeding on to solid modeling.

The graphics faculty face several challenges when teaching graphics. While the course does not have any prerequisites the sections have traditionally been a 50-50 mix of students with and without previous drafting experience. This has posed several problems. First, was that the students with previous experience tend to believe they already knew everything and tuned out the lectures and/or turned in less than adequate work. Second, the pace was very fast for the beginning student. Third, was the wide range of students' visualization skills. Students with weak visualization skills generally perform poorer in a graphics class than those with strong visualization skills.[5] Another area of difficulty was dimensioning. It has been one of the hardest topics to teach, and for students to grasp. Stressing the importance of following the dimensioning rules, grade deductions, starting to learn dimensioning earlier in the semester, etc., did not seem to improve the students' understanding of dimensioning or their dimensioning skills. Not only must the students learn all of the ASME Y14.5M-1994 dimensioning standards rules, they must learn which rules may be broken and in what order.[1] They also have to understand why proper dimensioning is important and how improper dimensioning can change design intent.

Design intent means how a part is intended to be used. Dimensioning is used to convey design intent to the manufacturer. Over dimensioning causes tolerancing stack up problems and under dimensioning results in unmanufacturable or incorrectly sized parts. For example, let us examine a portable phone battery compartment cover. The overall width of the cover is important so the cover blends smoothly with the rest of the phone. The wall thickness of the cover is important because if the wall is too thin it could result in the plastic breaking and if the wall is too thick it will use more plastic than necessary raising the manufacturing costs. The thickness of the wall is also used to position the guide which runs along the groove in the handset. The thickness of the guide is also important. If it is too wide it will not fit into the groove on the handset and if too small the cover will move around on the back of the phone making the phone appear poorly made. The battery is held in place by a properly sized pocket in the phone, therefore the distance between the two tabs on the cover is not important.

While the graphics faculty were not completely successful in implementing active learning the fall before, the faculty did feel they were on the right track. The faculty felt hands-on exposure to machining processes would help the students understand why proper dimensioning was important. However the MET students do not take a machine operations course until the end of their sophomore year and the PLET students are not required to take any machining courses. Therefore the faculty had to find a way to address the concept of simple manufacturing processes without going to a machine shop and using more class time. It was also decided the traditional method of teaching multi-views was not allowing for a smooth transition to solid modeling. After much brainstorming the decision was made to combine teaching solid modeling strategies, design intent, and dimensioning while teaching multi-views. This would be accomplished by having the students sketch the object feature by feature. As each feature was sketched the dimensions would be added, while keeping design intent in mind. At the same time a clay model would be created feature by feature allowing the students to experience simple manufacturing processes. In order for this to work the students would have to work in teams. A plan was created and modified as the semester progressed.

The Original Plan:

The in-class activities would be called Hands-On exercises and not graded to encourage trial and error without penalty. Students were assigned to work in teams of four. Each team member was to choose a role – reader, sketcher, modeler, inspector. The team members were to first prepare for their role. The reader was assigned a 3-dimensional object to verbally describe to the sketcher and modeler much like a long distance phone call to a business across the country. The reader had to obtain necessary dimensions and decide which side of the object would be the front view. The sketcher was to sketch the border and title block on engineering paper, while the modeler prepared his/her tools and clay. When all team members were ready, the reader gave the sketcher and modeler the overall dimensions so the sketcher could block in the required views and the modeler could make sure his block of clay was bigger than needed. The sketcher had to calculate the spacing needed to center the principal views within the border and title block. The inspector was to watch both the sketcher and the modeler to make sure their work was correct. The inspector also had to make sure a minimum of ½" clear space between dimensions and/or views and that the views were properly arranged, aligned and centered on the page. When finished, the reader verbally described the object's most descriptive shape and size to the sketcher and modeler while keeping design intent in mind. The sketcher sketched this shape in the required views and properly dimensioned it, while the modeler scribed the shape on the block of clay to size and then cut along the scribed lines. This step was repeated for each feature until the object was finished. The inspector was to also check that 2-place decimal, unidirectional chain dimensions, following ASME Y14.5M-1994 dimensioning rules, were used on the sketch and inspect the clay model to verify that it was manufactured within the given general tolerance of ±.01.[1] This lead to discussions on design intent, over dimensioning, under dimensioning, and what was required in order for the part to pass inspection. For example, in order for the part to pass inspection more accurate measuring tools, cutting tools, time, etc., were needed. This also led to a discussion on the closer the tolerance the more expensive the manufacturing cost. In other words, if making a part for a toy company .13±.01 would be less expensive to manufacture to than .125±.005, keeping the cost of the toy down. Team members were to change roles for each hands-on assignment in order to experience each position.

The Revised Plan:

The instructors had a difficult time checking the students work, keeping all of the teams on track and following the hands-on instructions. After completing several hands-on assignments the teams were moved to the white boards so the sketchers could sketch on the board instead of paper. This allowed the sketchers to use different colored markers for each feature and the instructors to easily keep an eye on each team's work.

After several more hands-on assignments, the instructors noted the students were still struggling with dimensioning feature by feature. The main problem seemed to be understanding the extrusion process. While the extrusion process had been discussed when talking about sketching feature by feature, some students still had a difficult time with this concept. A Play-Doh set was brought in to demonstrate extrusion. A two dimensional shape was selected on the Play-Doh template. The 2D shape was then sketched on the board and dimensioned. This used two of the three dimensions – height and width. This 2D shape was then sketched in the rest of the required views. The third dimension, depth, was the extrusion length. The clay was extruded and the third dimension was added to the views on the board. This same procedure was then demonstrated in Pro/ENGINEER. The 2-dimensional shape was sketched, dimensions added, and then extruded adding the 3rd dimension. The students were then instructed to sketch and dimension the feature's 2-dimensional shape in all the required views. The third dimension was then added in the appropriate views. This method was repeated for each feature. In addition, the modeler for each team was told to wait until their team sketcher was finished and then create the model from the sketch on the board feature by feature. This method worked well, allowing the students to find their own mistakes, such as missing dimensions. Because this approach was different from the traditional teaching methods used to teach mutli-views and dimensioning, it challenged all students, including the ones with previous drafting experience. To make sure each student understood the day's work, each student was required to complete their own sketch on engineering paper with dimensions for the next class. At the end of this module the instructors randomly selected one of the sketches to collect and grade.

A survey was given at the end of the semester. The students were asked to check which exercises helped to increase their visualization skills, increase their dimensioning skills, and helped to prepare them for creating and dimensioning models in Pro/E? The following results were obtained and are ranked from most helpful to least.

Percent of students that felt the following items helped to increase their visualization skills.

75.0% Creating models from clay
66.7% Traditional glass box method.
62.5% Sketching the object on the board.
56.3% Modeling the object from the sketch on the board.
45.8% Writing the modeling strategy on paper.
43.8% Describing the object verbally to someone else.
31.3% Listening to someone verbally describe the object.
27.1% Inspecting the part (taking measurements).
25.0% Modeling the object from a verbal description.

Percent of students that felt the following items helped to increase their dimensioning skills?

25.0% Dimensioning modules.
14.6% Sketching the object on the board.
12.5% Traditional glass box method.
12.5% Inspecting the part (taking measurements).
12.5% Writing the modeling strategy on paper.
10.4% Creating models from clay.
8.3% Modeling the object from the sketch on the board.
4.2% Modeling the object from a verbal description.
4.2% Describing the object verbally to someone else.
2.1% Listening to someone verbally describe the object.

Percent of students that felt the following items helped to prepare them for creating and dimensioning models in Pro/E?

- 29.2% Sketching the object on the board.
- **22.9% Creating models from clay.**
- 18.8% Writing the modeling strategy on paper.
- 14.6% Dimensioning modules.
- 12.5% Traditional glass box method.
- 10.4% Modeling the object from the sketch on the board.
- 10.4% Describing the object verbally to someone else.
- 8.3% Listening to someone verbally describe the object.
- 8.3% Modeling the object from a verbal description.
- 8.3% Inspecting the part (taking measurements).

While 75% of the students felt creating models from clay helped to increase their visualization skills, the first exam did not show a significant improved compared to previous years. However during class time the students' level of frustration was lower and self-confidence higher.

Future Plan:

While the instructors feel they are on the right track, several areas need to be strengthened. For example, explaining the extrusion process with the aid of Play-Doh needs to be presented before the students complete the first multi-view Hands-On exercise. Another change will be the addition of writing out Pro/ENGINEER modeling strategies. Before each student was allowed to start modeling in Pro/E, a modeling strategy had to be submitted for instructor's approval. While the students ranked writing the modeling strategy 45.8% in helping to strengthen visualization skills, it only ranked 12.5% in improving dimensioning skills. Therefore, applicable portions of the modeling strategy will added at the beginning of multi-views. The modeler and inspector will be required to write out a modeling strategy before verbally describing the object to the sketcher. The modeling strategy for Figure 1 is shown in Figure 2.

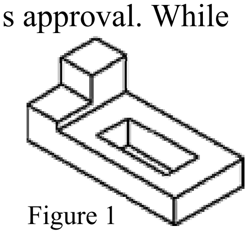
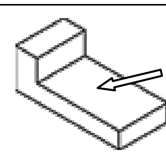
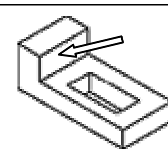
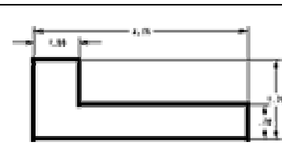
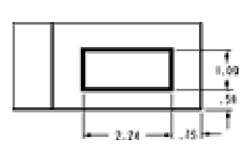
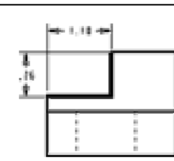


Figure 1

	Main Feature	**2nd Feature**	**3rd Feature**
Sketch Plane (Horizontal, Frontal, Profile, or existing surface)	Frontal		
2-Dimensional Shape of Feature with dimensions following design intent (DI)	 DI: material is important	 DI: size of slot is important and must be located from the front right corner	 DI: size notch is important

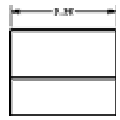
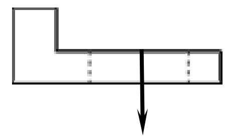
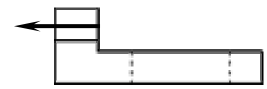
Extrusion Distance	Depth 2.20 	Thru All 	Thru All 

Figure 2

Conclusion:

One of the main goals of the course is for the students to conceptualize (visualize) a model (end product) and understand the dimensioning requirements. Several different methods were use simultaneously involving clay modeling, glass box theory, and laying out modeling strategies on paper. As shown in the surveys, 75% of the students felt the clay modeling was the most effective method in improving their visualization skills. Therefore the instructors will continue integrating clay modeling into the course. The faculty anticipate the students understanding of dimensioning and their dimensioning skills will also improve when the suggestions made in the Future Plan section are incorporated into the hands-on exercises.

1. ASME Y14.5M -1994. “Dimensioning and Tolerancing”.

2. Gieskecke, F.E., Mitchell, A., Spencer, H.C., Hill, I.L., Dygdon, J.T., Novak, J.E., Lockhart, S. (1998) *Modern Graphics Communication*. Upper Saddle River: Prentice-Hall, Inc.

3. Forsman, D., Holliday-Darr, K., Lobaugh, M. (June 2002) “Process Education in Computer Graphics”. *2001 American Society for Engineering Education 2001 National Conference proceedings*. CD Index number 970.

4. Pacific Crest (2002). Process Education. Retrieved January 12, 2002, from http://www.pcrest.com/phil.htm

5. Blasko, D, Holliday-Darr, K. (April 1999). “Engineering and psychology: joint project on visualization & engineering graphics education.” *North Central Section of American Society of Engineering Educators proceedings.*

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